Vertical cavity testing at Fermilab

Grigory Eremeev / Fermilab

PIP-II Technical Workshop

11/29/2020

A Partnership of:

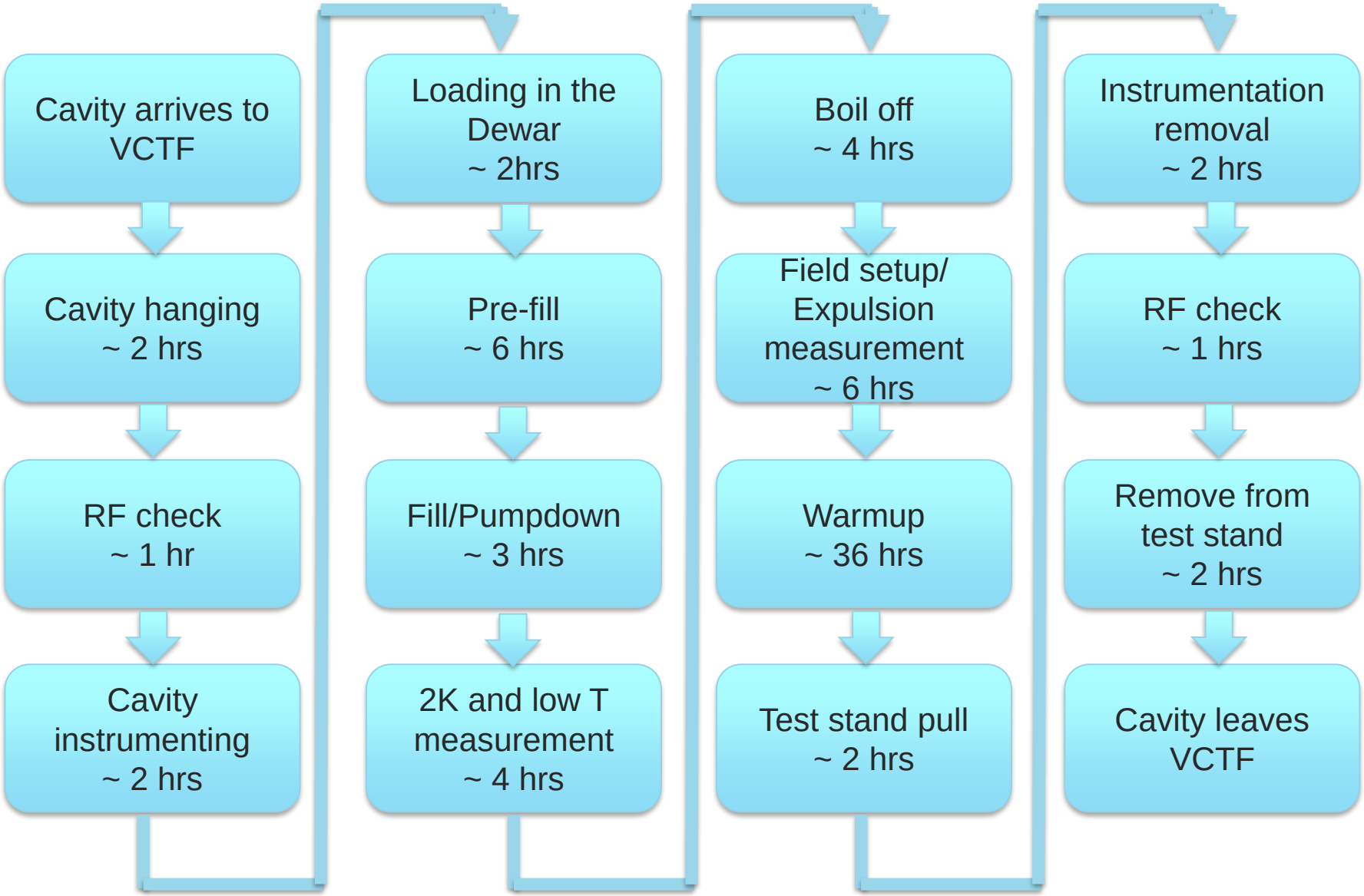
US/DOE
India/DAE
Italy/INFN
UK/UKRI-STFC
France/CEA, CNRS/IN2P3
Poland/WUST

VCTF general overview

- Three testing dewars
- Multiple test stands
- 3-4 days turnaround time
- Multiple cavities can be tested in one cooldown down to 1.4 – 1.5 K: three jacketed 1.3 GHz 9-cell cavities, four 1.3 GHz 1-cell cavity, etc.*
- Two RF systems: one analog system(up to 4.2 GHz) and one digital RF system(up to 13 GHz)
- Dewar/cavity instrumentation: liquid level, dewar diodes, radiation detectors, on-cavity cernox sensors, single-axis magnetic probes, OST, thermometry, active magnetic compensation, fast thermometry

* Currently only one LB650/HB650 5-cell cavity can be tested per cooldown

VCTF testing layout



Typical VTS cycle is about 72 hours

Preparation and Installation of a Cavity in the Vertical Test Stand (VTS)

464240 Rev. F

Series	Serial No.	Job No.	Task No.	Released By	Released Date	Status
HB650	B92D-RRCAT-502-0	482	See Job Page	Abraham Diaz	8/7/2020 7:55:28 AM	Closed

1.0 Abstract Top

1.1 This traveler is to be used during the preparation and installation of all cavities and instruments to be tested in the Vertical Testing Stand (VTS) Cryostat.

2.0 General Notes, Safety and Training Top

2.1 The bellows protection brackets top and bottom are not to be removed for any reason. Also, verify the presence of the tuner split rings and arms. Contact a appropriate authority for addition information if needed.

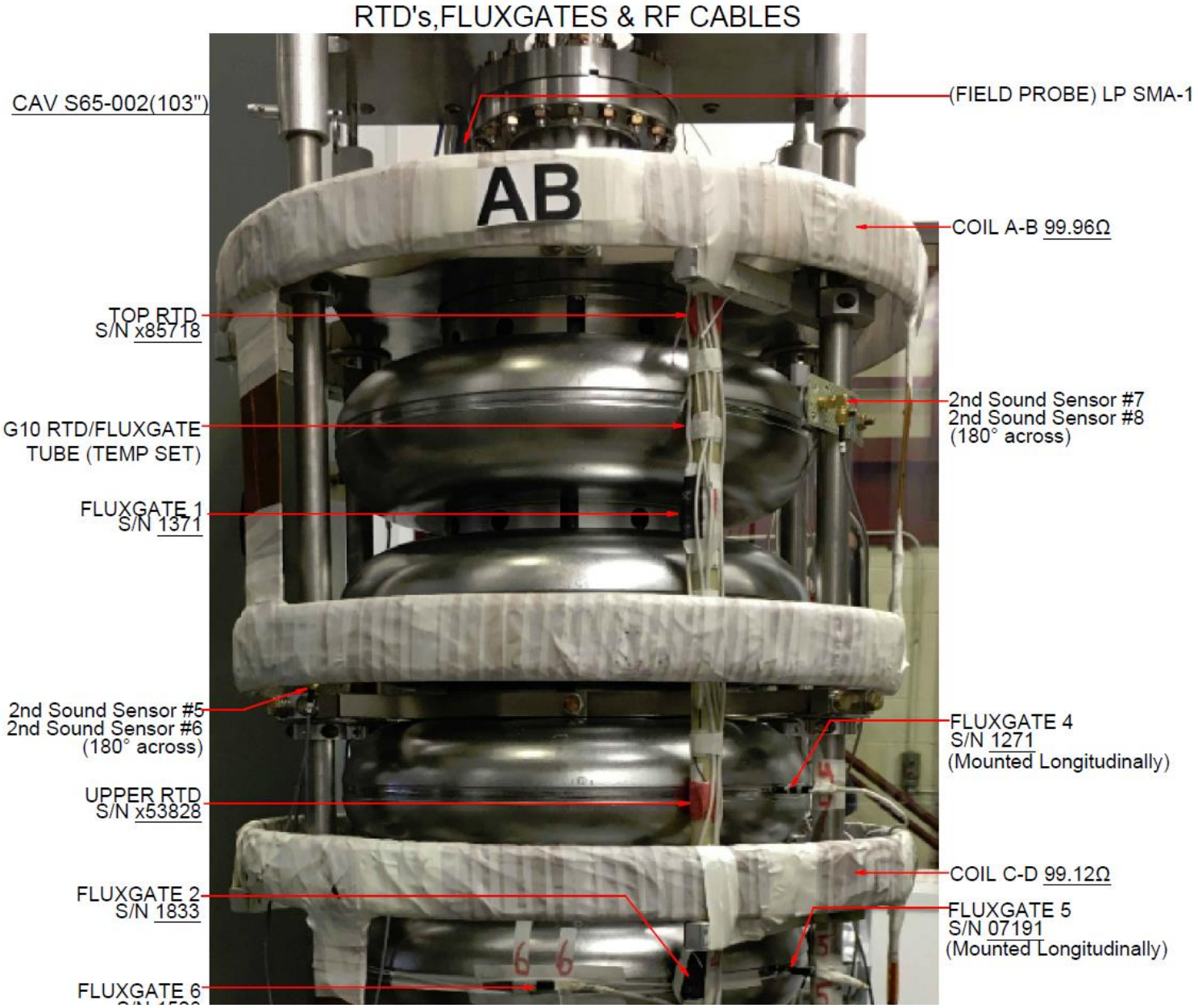
2.2 White (Lint Free) Gloves (Fermi stock 2250-1800) or Surgical Latex Gloves (Fermi stock 2250-2494), or equivalent, shall be worn, as required, by all personnel when handling all parts before and after they have been prepared/cleaned and during all inspection and measuring procedures. All personnel must wear steel-toed shoes and while handling a cavity.

2.3 All activities related to cavity handling are to be performed in accordance with all applicable Fermilab ES&H, Radiological Control, Divisional, and Departmental policies, procedures, and requirements. Failure to do so can result in both increased risk to personnel and damage to government property, and may result in disciplinary action. Refer to the following document for cavity handling and preparation:

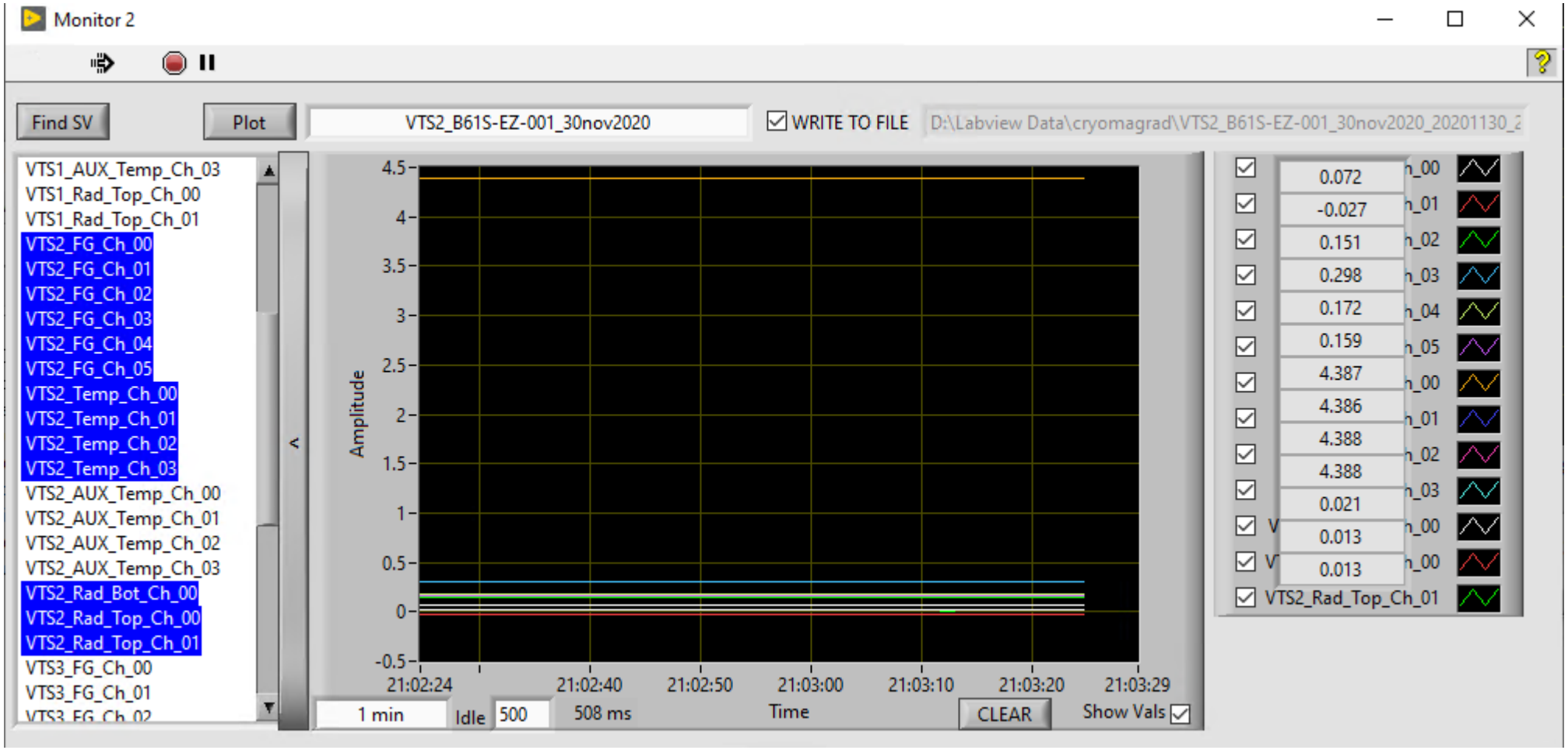
2.4 Cavity handling operations may only be carried out by trained individuals. Mechanical Technicians perform all activities and tasks related to the preparations which take place in IB1 and the installation of the cavity on to the VTS top plate. Included in the installation activities are leak checking of the of the line to the right angle valve and top plate flanged connections, leak checking of the active pumping line connections. Also included in this checklist there will be all information for all instrumentation that each cavity has mounted on as well as coils used. All PI, and PT and SMA cables will be included. There will also be cool down instructions included in this check list to inform Techs and Cryo operators of Helium liquid levels needed and test plans for each cavity.

VCTF cavity instrumentation

PIP-II cavity instrumentation:
Six fluxgates (MAG-F)
Four Cernox temperature sensors
Helmholtz compensation coils
Eight OST sensors

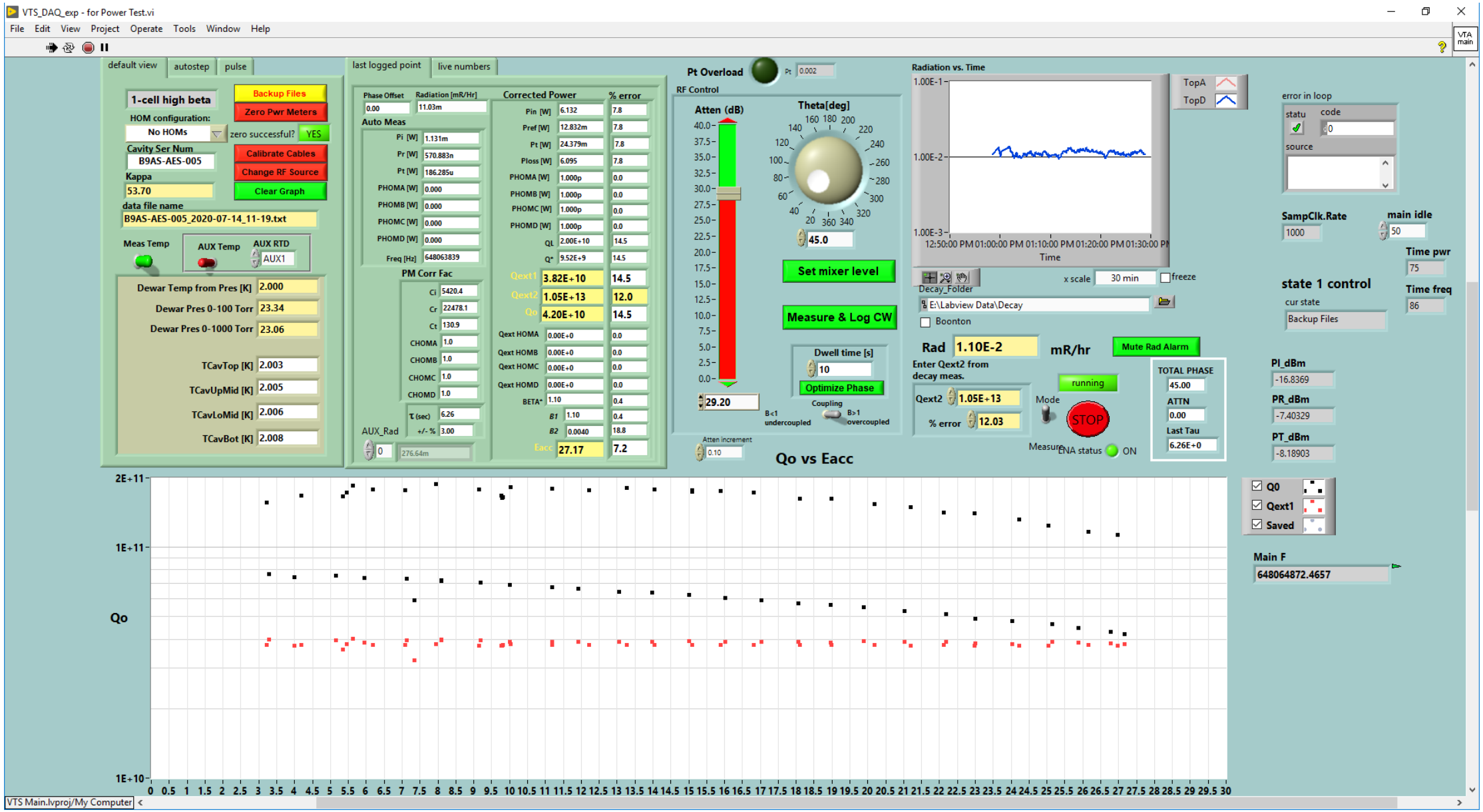


VCTF cooldown data recording

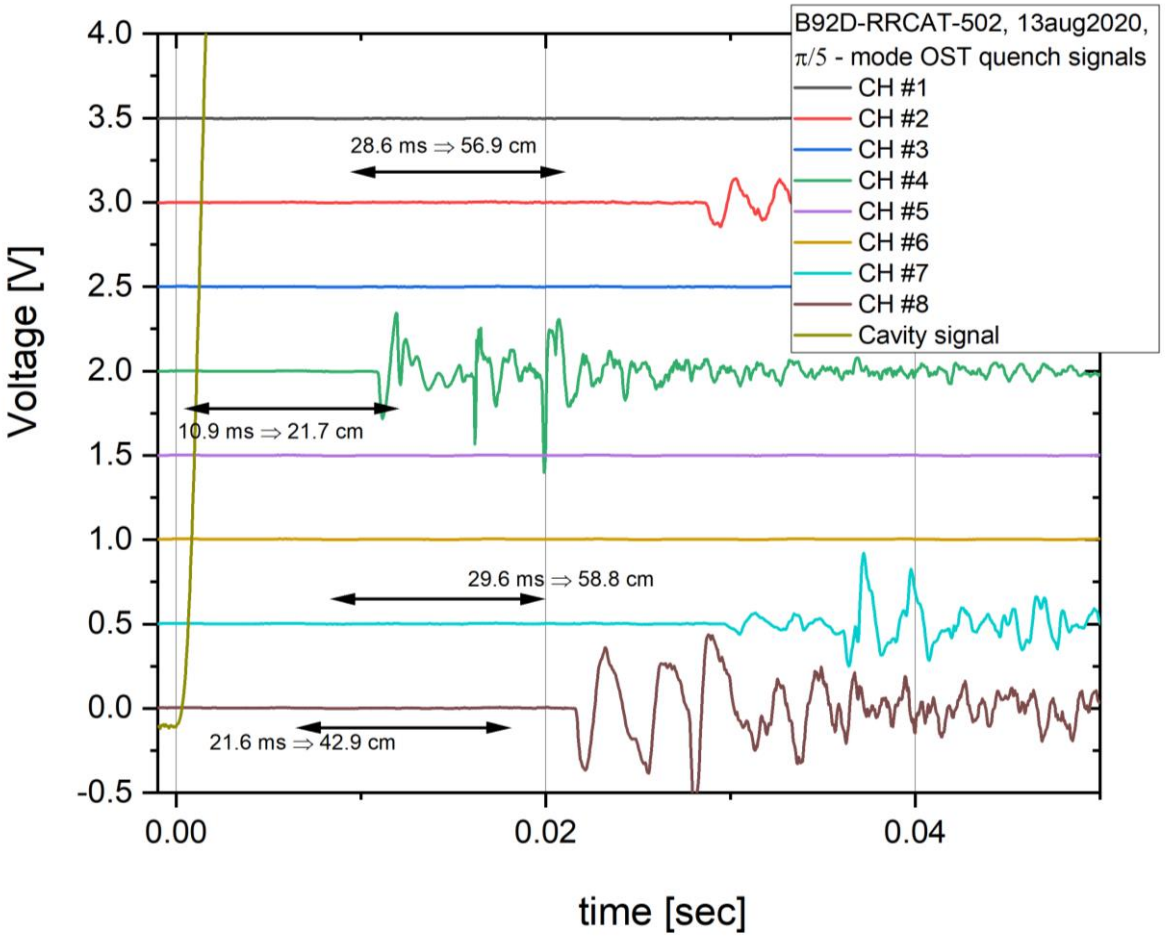


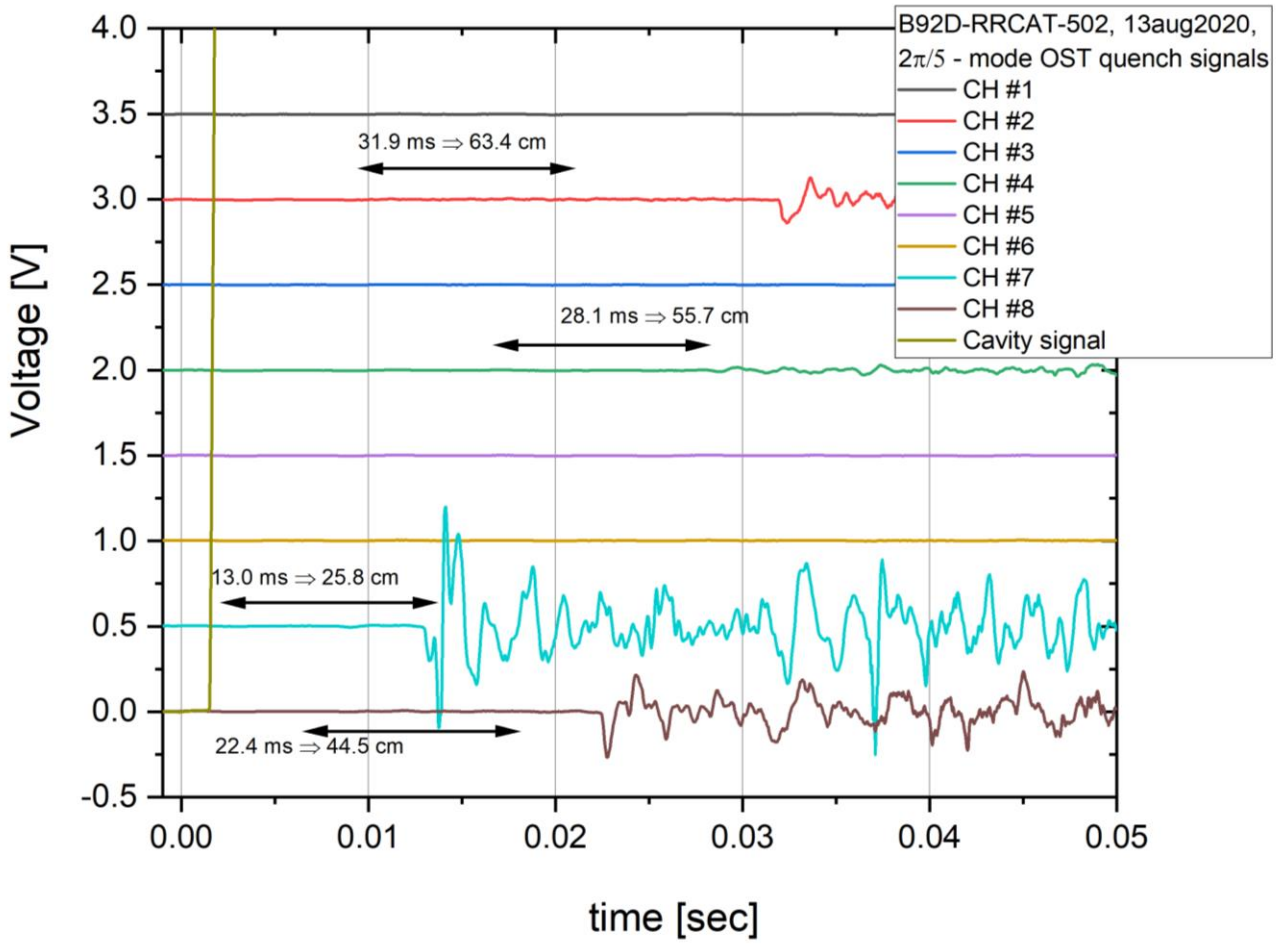
Typical cooldown involves an uninterrupted pre-fill to a certain level on the swing shift the day before

VCTF RF measurement



VCTF: an example of OST results





650MHz 5-cell Cavity 2K VTS Testing (RFCD, HB650, LB650)

464364 Rev. A

Series	Serial No.	Job No.	Task No.	Released By	Released Date	Status
HB650	B92D-RRCAT-502-0	482	See Job Page	Grigory Eremeev	8/16/2020 2:25:04 PM	Closed

Rad_{max}: ***68.4 mR/hr*** *Intial FE onset E_{acc}* ____ **MV/m** *Final FE onset E_{acc}* ____ **MV/m**

Comment on Performance Limitation: ***Limited by Quench @ Eacc = 11.2 MV/m in pi-mode at both 2 K and 1.5 K. Radiation spikes likely due to multipacting. OST data indicates that the quench was in 5th cell.***
4pi/5 mode measurements @ 1.5 K: Quench at end cell gradient Eacc = 11.2 MV/m. OST data indicates that the quench was in 5th cell, same as in pi-mode.

3pi/5 mode measurements @ 1.5 K: Quench at end cell gradient Eacc = 9.1 MV/m. Some X-rays spikes ~ 1 mR/h. OST data indicates that the quench was in 3rd cell.

2pi/5 mode measurements @ 1.5 K: Quench at end cell gradient Eacc = 7.4 MV/m. Multipacting processing. OST data indicates that the quench was in 4th cell.

1pi/5 mode measurements @ 1.5 K: Quench at end cell gradient Eacc = 3.5 MV/m. Multipacting processing.X-rays spikes during quenching. OST data indicates that the quench was in 3rd cell, same as in 3pi/5 mode.

Comment on Multipacting, if Applicable: ***Multipacting was present, seemed to be processed in pi-mode, but was again present in other mode, so it likely was not completely processed.***

Residual resistance (if available): ____ **nΩ**

6.9 Upload Files.

B92D-RRCAT-502_OST_4pi_5_mode_14aug2020

B92D-RRCAT-502_OST_3pi_5_mode_14aug2020

A few comments to high power testing:

How do you handle passband mode excitation?

- Typcially, we will try to take a CW measurement before second mode gets excited

What are challenges to meet Q0 and Eacc specifications?

- Multipacting, early quenches, and FE have presented challenges during B90 cavity testing.
-

How do you plan to characterize flux expulsion?

- Magnetic field is set up to a certain level using Helmholtz coils and fluxgates (~ 100 mG), then several warmups/cooldowns are down, with warm-ups to progressively high temperatures (10 K, 15 K, 30 K, 50 K, 60 K, 90 K, 300 K)

PIP-II jacketed cavity minimal acceptance criteria (draft)

PIP-II Functional Requirements Specification Guidance Document

Requirement ID	Requirement Definition (or Parameter)	Performance Criteria or Quantity	Units	Verification Method	Procedure Summary	Reference Document
2.4. RF performance (2K)						
	Cavity accelerating gradient (Eacc)	≥20	MV/m	2K vertical testing	Per vertical test procedure	TRS: ED0009658 Vertical test traveler
	Cavity unloaded quality factor (Q_0)	≥2.6e10	@17 MV/m	2K vertical testing	Per vertical test procedure	TRS: ED0009658
	Cavity Pi mode frequency	Frequency within 650.10-650.25	MHz	Network Analyzer		
	Cavity unity coupler	External Q within 1.5e10-2.5e10 (>?)		Network analyzer		
	Cavity field probe	External Q within 7e11 and 4e12 (?)		Network analyzer		TRS : ED0009658
	Field emission onset accelerating gradient	≥20	MV/m	2K vertical testing	Per vertical test procedure	TRS: ED0009658
	Field emission at 20 MV/m	<50	mR/h	Measured at two meter distance from cavity behind an equivalent of 2-in thick steel plate	Per vertical test procedure	TRS (?)
	Multipacting	Free of multipacting between 15-19	MV/m	2K vertical testing	Per vertical test procedure	TRS : ED0009658

Requirement ID	Requirement Definition (or Parameter)	Performance Criteria or Quantity	Units	Verification Method	Procedure Summary	Reference Document

PIP-II 650 MHz Vertical Cavity Test Facility Requirements Specification (draft)

6. Functional Requirements

Table 6-1. General Requirements

Requirement #	Requirement Statement
F-121.***	VCTF should contain RF systems capable of achieving nominal accelerating gradients in the cavities.
F-121.***	VCTF should contain RF systems capable of measuring intrinsic quality factors of cavities.
F-121.***	VCTF should provide the ambient magnetic field magnitude below 5 mG on cavity surfaces.
F-121.***	VCTF shall be capable of cooling down cavities from 45 K to 4.5 K at a rate ≥ 20 K per minute.
F-121.***	VCTF shall be capable of cooling down cavities from 175 K to 90 K at a rate ≥ 20 K per hour.
F-121.***	VCTF shall have thermometry to allow for monitoring and control Dewar temperature under all expected operational scenarios.
F-121.***	VCTF shall have internal magnetic field probes to allow for monitoring and control under all expected operational scenarios.
F-121.***	VCTF shall have cavity diagnostics to allow for monitoring and control under all expected operational scenarios.